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DLA-93-P10096

COMPUTATION OF PRODUCTION LEADTIME SAVINGS

November 1992

OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE

DEPARTMENT OF DEFENSE
DEFENSE LOGISTICS AGENCY

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Maj Bruce Colletti, USAF

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DEFENSE LOGISTICS AGENCY
OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE
CAMERON STATION
ALEXANDRIA, VA 22304-6100

DEFENSE LOGISTICS AGENCY
HEADQUARTERS
CAMERON STATION
ALEXANDRIA, VIRGINIA 22304-6100

DLA-LO

FOREWORD

The purpose of this study was to develop a tool for use by Value Engineers to determine how much was saved through a VE study. Since the answer to this question is NSN specific and is a function of inventories, safety levels, holding costs and ordering costs, the model was constructed to consider NSN level parameters and inventory practices (e.g. Economic Order Quantity and Variable Safety Level equations) currently programmed in SAMMS. The model uses a total of nineteen NSN specific parameters to determine savings which may result from a VE study which leads to production leadtime savings or price reduction.

This report presents work done by the Defense Logistics Agency Operations Research and Economic Analysis Management Support Office (DLA-DORO). These offices in DLA are thanked for their guidance during this study:

- Directorate of Technical and Logistics Services, Engineering Programs Division (DLA-SE), Ms. Mary Hart and Mr. Tony Berta;

- Directorate of Supply Operations, Supply Management Division (DLA-OS), Messrs. Mike Pouy and Hal Crawford;

- Defense General Supply Center (DGSC), Technical Operations Division, Value Engineering Branch (DGSC-SVA), Mr. Ron Edmunds;

- DGSC Office of Planning and Resource Management, Operations Research and Economic Analysis Office (DGSC-RO), Messrs. Tom Brooks and John Neblett.

Christine L. Gallo
CHRISTINE L. GALLO
Deputy Assistant Director
Policy and Plans

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

SECTION 1
INTRODUCTION

1.1 BACKGROUND

Production Leadtime (PLT) is how long it takes to deliver an item after it is ordered. By reducing PLT, Defense Logistics Agency (DLA) Value Engineers (VE) hope to lower the total item costs and thus create dollar savings (i.e., PLT savings). Although a PLT savings formula now exists, VEs have long sought a more accurate and defensible formula.

On two earlier occasions in 1981 and 1988, the DLA Engineering Programs Division (DLA-SE) asked the DLA Operations Research and Economic Analysis Office (DLA-LO) to improve the existing PLT savings formula. Although both efforts were initially thought to be too complex by the VE community, the weakness in the existing formula eventually led to renewing the study in December 1991.

1.2 PURPOSE

The purpose of this study is to replace the old PLT savings formula with one that is more accurate and defensible.

1.3 OBJECTIVES

The general objectives of the study are to:

(1) complete a background review of previous work in this area, to include becoming familiar with aspects of the Standard Automated Materiel Management System (SAMMS);

(2) understand the methods used in the VE community to compute PLT savings and to arrive at a general approach that has their concurrence;

(3) develop a mathematical approach that emulates, as well as possible, the various costs that are impacted by changes in PLT; and

(4) incorporate the mathematical approach in a personal computer based tool for use by the VE community in the DLA hardware centers.

1.4 SCOPE

The study will only consider demand-oriented replenishment items with a fixed or variable safety level. This eliminates medical items, subsistence items, clothing and textile items, numeric stockage objective items, and non-stocked items.

Backorder penalty costs are not assessed by DLA and therefore are not included. Thus, the impact of PLT changes on DLA customers is ignored.

This study does not compute augmented safety levels for weapon system items. This means that safety levels could be understated. However, augmented safety levels are often smaller than the variable safety level, and the larger of the two is used in SAMMS.

SAMMS formulas for variable safety level and economic order quantity are obeyed. This allows VEs to defend audited PLT savings by closely emulating existing SAMMS procedures.

SECTION 2
METHODOLOGY

2.1 DEFINITIONS

Before reviewing the background, supporting material, and mechanics of the new PLT savings formula, these frequently used terms need to be defined:

- Economic order quantity (EOQ) is the number of units bought in one order that minimizes average total variable cost.
- Holding cost is the expense to maintain stock and considers investment, obsolescence, storage, and other (e.g., theft) costs.
- Material cost is the cost paid for the items ordered.
- Ordering cost is the cost of placing an order.
- Reorder point is the stock position that triggers a buy order.
- Safety level is the quantity of material which is required to be on hand to permit continued operation in the event of minor interruption of normal replenishment or unpredictable fluctuation in demand.
- Total variable cost (TVC) is the sum of holding, material, and ordering costs.

2.2 REVIEW PREVIOUS STUDIES

As mentioned earlier, the search for an accurate PLT savings formula has a long history. In a March 1982 study, DLA-LO developed a series of formulas that used a TVC approach and attempted to emulate SAMMS. It was thought that true costs are total system costs and not just changes in the relative cost of leadtime demand.

In March 1990, the VE community presented a paper to DLA that challenged a preliminary computer model developed by the DLA Operations Research and Economic Analysis Management Support Office (DORO) which encoded the March 1982 formulas. The March 1990 paper mathematically defended the traditional VE formula. A review of that paper revealed that safety levels were not used in order to simplify the formula. DORO found other methods in the paper that appeared to be flawed.

As a result of initiating this project in December 1991, a joint review of both studies was made by DORO and a representative for VE in order to develop a mutually agreeable approach. During that review an error was found in the DLA-LO 1982 study where the leadtime demand was double counted (Appendix A).

2.3 IDENTIFY DATA AND SOURCE DOCUMENTS

After reviewing existing studies, the next step in the methodology was to identify the appropriate data and how SAMMS used it. Item data came from each supply center's Supply Control File, and general rates came from each supply center's Management Policy Tables 007 and 008. These tables generally contain different SAMMS factors. However, holding rates were also taken from the December 1991 "Multiple Cost EOQ Study" by Synergy Inc. SAMMS EOQ and safety level formulas came from DLA Manual 4140.2 Vol II Part 2 D186-187, "Supply Operations Manual, Defense Supply Center, Supply Operating Procedures."

2.4 DEVELOP PLT SAVINGS METHODOLOGY

The next step in the methodology was to combine data and SAMMS formulas into a single PLT savings formula. The resulting formula (Appendix B) considered how changes in PLT and price affect total variable costs and not just changes in leadtime demands as did the traditional PLT savings formula. In a nutshell, the new formula computes TVC for both the original PLT and price and the new PLT and price. Computations over corresponding time periods are compared and the resulting difference is the PLT savings. Costs included in the calculations are holding costs, ordering costs, and the cost of the material. The key variables that affect savings computations are EOQ and safety level.

2.5 COMPUTING EOQ AND SAFETY LEVEL

Both EOQ and safety level are affected by price, while only safety level is affected by PLT. Of the many ways to compute EOQ, SAMMS uses the Wilson formula (Appendix C). The results of the Wilson EOQ formula are adjusted within SAMMS due to shelf life and other considerations. Finally, a constant ordering cost is assumed in SAMMS when computing EOQ. Although in reality ordering cost varies with the dollar amount of the buy, it was decided to keep the constant ordering cost in order to conform to SAMMS calculations.

SAMMS uses the Presutti-Trepp formula, without significant modification, to compute safety levels. This formula was developed in 1970 by Messrs. Victor Presutti and Richard Trepp of Air Force Logistics Command. The Presutti-Trepp safety level formula is mathematically complex, uses many factors, and is therefore difficult to understand. For the technical reader the full description is presented in Appendix D.

Results of the EOQ and safety level formulas may not respond as expected to some changes in price and PLT. This is caused by the mathematical construction of the formulas. For example, if an item has no safety level, any decrease in PLT of any size may not change the results of the PLT savings formula. Generally speaking, however, lower price boosts EOQ and safety level and lower PLT shrinks safety level.

2.6 RECONCILING COMPUTED AND ACTUAL EOQ/SAFETY LEVEL

The EOQ and safety level formulas rely on item specific data and supply center specific rates. For example, safety level uses item data such as PLT, price, and average requisition size; and supply center rates such as ALPHA factor, backorder rate, and system constant.

It was found that computed EOQ and safety levels do not always agree with what is in SAMMS. Computed values may be manually overridden by supply center personnel. For example, in a stratified random sample of 1129 Construction Commodity items taken in the course of the study, 23 percent had different actual and computed safety levels. This approximate percentage has appeared in another DORO study of 120 thousand General Commodity items.

When the computed and actual EOQ/safety level of an item differ, it is necessary to attempt a reconciliation in order to make the EOQ and safety level in the PLT savings formula conform with actual (overridden) data in SAMMS. This reconciliation methodology is presented in Appendices C and D. Simply stated, by recomputing ordering costs for EOQ computations and the system ratio for safety level computations, computed and actual values in SAMMS are reconciled.

SECTION 3
PLT SAVINGS MODEL

3.1 DESCRIPTION

It is too difficult to manually implement the new PLT savings formula. The EOQ and safety level formulas are inherently complex and the adjustments described above in the methodology section greatly increase that complexity.

Because of the difficulty of computations, it is necessary to implement the new formula on a personal computer as a tool. The tool is used for rapid and interactive item level study. Users may specify different item and rates files, change one or more general rates, and change the PLT and/or price of an item. Displays of savings reports and graphs are available. This stand-alone tool has an online user's manual and was written in the languages PDCPROLOG 3.21 and TURBO C++ 1.0. The following subsections describe each component of the PLT savings analysis tool.

3.2 ITEM DATA ENTRY (MAIN SCREEN)

Users select an item data file from a menu of such files. Once a file is opened, data on each item in the file is displayed sequentially upon demand. Item data used in the SAMMS EOQ and safety level formulas appear, but only PLT and price may be changed. On-line help texts describe main screen options and give an overview and points of contact (for the tool and for item data). There also are available detailed descriptions of two savings reports.

3.3 SAVINGS REPORTS

After entering the new PLT and/or price, users may choose between two savings reports. These are essentially the same except that one includes material costs (figure 3-1) and at the request of DLA value engineers, the other does not (figure 3-2). This latter report displays the T-Factor (a factor that relies upon the ordering cost; see Appendix C) and recomputed system ratio instead of the material costs.

Each report has three parts. The first shows procurement cycle length, safety level, and EOQ. Each of these data elements are shown in three different ways: as they appear in SAMMS (actual), as they appear after reconciliation (adjusted actual), and as computed under changed PLT and price (new).

The second part of the report focuses on the "VE-Period." The VE-Period starts when the old and new on-hand inventories start to differ and stops at the end of the first new buy cycle. In other words, the VE-Period is the time spent consuming safety stock PLUS the time in backordered status PLUS the length of the first new procurement cycle. This part of the report shows holding, ordering, and material costs. It also shows total savings, how long safety stock is consumed, backorders, and size of the first buy.

NSN=3040000450504	Cycle Length	Safety Level	Economic Order Qty	UnitPrice	PLT	17JUL1992
Actual	6 mos	11	6.00	816.79	570	
Actual Adjusted	6 mos	11	6.00			
New	7 mos	10	7.00	600.00	400	

------- VE Period Costs -------

	Holding +	Ordering +	Material =	Total
Actual	1342.26	416.56	9801.48	11560.30
Actual Adjusted	1342.26	416.56	9801.48	11560.30
New	924.75	208.28	4200.00	5333.03
Savings (Actual Adjusted - New)				6227.27
Consume Safety Level Stock (OneTime)				1.00 mos
BackOrders				0
FirstTime Buy Size (units)				7

---------------- Cumulative Savings ----------------

	Total =	Holding +	Ordering +	Material
OneTime	5178.45	69.43	208.28	4900.74
+ 1Year	7104.39	593.89	208.28	6302.22
+ 2Year	9064.33	1152.35	208.28	7703.70
+ 3Year	11058.27	1744.81	208.28	9105.18
+ 4Year	17434.99	2311.77	416.56	14706.66
+ 5Year	19377.93	2853.23	416.56	16108.14
+ 6Year	21354.87	3428.69	416.56	17509.62

Figure 3-1. PLT Savings Report (with material costs)

NSN=3040000450504	Cycle Length	Safety Level	Economic Order Qty	UnitPrice	PLT	17JUL1992
Actual	6 mos	11	6.00	816.79	570	
Actual Adjusted	6 mos	11	6.00			
New	7 mos	10	7.00	600.00	400	

------- VE Period Costs -------

	Holding +	Ordering =	Total
Actual	1342.26	416.56	1758.82
Actual Adjusted	1342.26	416.56	1758.82
New	924.75	208.28	1133.03
Savings (Actual Adjusted - New)			625.79
Consume Safety Level Stock (OneTime)			1.00 mos
BackOrders			0
FirstTime Buy Size (units)			7

-------- Cumulative Savings --------

	Total =	Holding +	Ordering
OneTime	277.71	69.43	208.28
+ 1Year	802.17	593.89	208.28
+ 2Year	1360.63	1152.35	208.28
+ 3Year	1953.09	1744.81	208.28
+ 4Year	2728.33	2311.77	416.56
+ 5Year	3269.79	2853.23	416.56
+ 6Year	3845.25	3428.69	416.56

SAMMS Factors

HoldRate	MaxCycle Length
0.17	12 qtrs

Computed T-Factor*
99.002424213

BackOrder Goal
24500

System Constant
211948669

Computed System Ratio*
0.00010817748991

* reconciles data

Figure 3-2. PLT Savings Report (less material costs)

The third part of a report shows the cumulative net savings in holding, ordering, and material costs. These savings are given for the first part of the VE-Period during which the first new buy is awaited (the "one time" period), and each year thereafter for 6 years. Costs are not discounted to present value.

3.4 GRAPHICAL DISPLAY OF SAVINGS REPORT

A graphical display is available to help explain and show the relationships of reported values by superimposing a graph of the old and new on-hand inventories. Periods of safety level consumption and backorder are highlighted. One look at how inventory activities shift and grow may greatly help to understand the output of the tool.

3.5 SUPPLY CENTER RATES

During an analysis users may need to change the supply center unique rates that affect EOQ and safety level computations. These factors are backorder rate, system constant, holding rate, Very Important Item (VIP) and non-VIP ALPHA factors, and the maximum procurement cycle length. Changed rates may be saved to a separate file for later recall. This allows one to study how sensitive savings are to these rates as well as changes in PLT and price. In order to allow VEs to rapidly analyze different scenarios, rate files and item data files may be freely matched. A separate pop-up help text is available to explain what actions can be taken from this screen.

3.6 COMPANION ITEM DATA FILE BUILDER

The PLT savings tool requires properly formatted item data in order to run. Gathering the data is challenging in itself let alone formatting it properly. To eliminate both problems, the Defense General Supply Center Value Engineering Branch (DGSC-SVA) is developing an automatic SAMMS utility to feed data to the PLT savings tool. Pending completion of this utility, DORO developed a separate PC-based tool to help build the required data files in the correct formats. This companion data building tool was distributed along with the PLT savings tool.

3.7 OTHER POTENTIAL APPLICATIONS

Others in DLA who are not Value Engineers have taken an interest in the PLT savings tool. These include members from the DLA Supply Management Division (DLA-OSP) and the DLA Production Division (DLA-PR). Several reasons may explain this interest:

- Self-documenting tool is easy to use on a personal computer.
- Tool is used for item level analyses.
- Tool relies on several important inventory factors and SAMMS formulas.
- Supply center rates and item PLT/price may be changed at will.

- Impacts of changed factors can be swiftly evaluated and displayed.
- New methodologies reconcile differences in theoretical/actual SAMMS EOQ and safety level values.

SECTION 4
CONCLUSION

We reached the following conclusions:

(1) The methodology implemented in the PLT savings tool is more accurate and defensible than the savings formula historically used by DLA VEs.

(2) PLT savings estimates can be defended during an audit as being based on DLA inventory policy.

(3) Although created for VEs, the PLT savings tool can be used for more general supply concerns and its scope extended.

SECTION 5
RECOMMENDATION

We recommend that:

(1) DLA Value Engineering offices replace their long-standing PLT savings formula with the new PLT savings tool whose methodology relies on changes in total variable costs.

(2) DLA VEs use the PLT savings tool to measure the effects that changes in both PLT and price jointly have upon savings.

APPENDIX A
ORIGINAL AND DLA-LO (MARCH 1982) PLT SAVINGS FORMULAS

APPENDIX A

ORIGINAL AND DLA-LO (MARCH 1982) PLT SAVINGS FORMULAS

1. The Production Leadtime (PLT) Savings formula in use since at least the late 1970's is:

$PLT savings = deltaPLT(days) * OldPrice * AverageDailyDemand

where:

- deltaPLT = Original PLT (days) - New PLT (days)
- OldPrice = Original Unit Price before the change in PLT
- AverageDailyDemand = 4 * Quarterly Forecasted Demand / 365

This formula arises by ignoring safety level and assuming that change in reorder point (which relies on PLT) accounts for PLT savings.

2. In March 1982, DLA-LO produced a more realistic formula that explicitly considered safety level and EOQ as computed by SAMMS. In February 1992, the Cost to Hold formula below was found to be wrong because it double counts leadtime demand items:

Annual Savings = TVC(old) - TVC(new)

where:

- TVC = Total Variable Cost
  = Cost to Order + Cost to Hold + Cost of Material
- Cost to Order = OrderCost * AnnualDemand / EOQ
- Cost to Hold =
  HoldRate * UnitPrice * (½EOQ + SafetyLevel + LeadtimeDemand)
- Cost of Material = UnitPrice * AnnualDemand
- EOQ = Economic Order Quantity
  = sqrt [2*OrderCost*AnnualDemand / (HoldRate*UnitPrice)]
- LeadTimeDemand = AnnualDemand * Leadtime(days) / 365
- SafetyLevel = ½MADLT * ln(X / Y)
  -- X = 2.56 * AvgRequisitionSize * EOQ * UnitPrice * BackorderGoal
  -- Y = ItemEssentiality * MADLT * SystemConstant * E
  -- E = 1 - exp(-EOQ*sqrt(2) / (1.25*MADLT)
  -- NOTE: SafetyLevel is capped by leadtime demand and 3.75*MADLT

APPENDIX B
DERIVATION OF PLT SAVINGS FORMULA

APPENDIX B

DERIVATION OF PLT SAVINGS FORMULA

References:

a. DLAM 4140.2 Vol II Part 2 D186 "EOQ Computation"
b. DLAM 4140.2 Vol II Part 2 D187 "Safety Level Computation"
c. DODI 4140.39 "Procurement Cycles and Safety Levels"
d. "More Ado About EOQ", Naval Research Logistics Quarterly, June 1970

1. This appendix develops a formula to compute savings due to an item's changed PLT and price. These definitions are largely from reference (c):

- EOQ is the unit buy that minimizes average costs.

- Holding cost is the expense to maintain stock and considers investment, obsolescence, storage, and other (e.g., theft) costs.

- Material cost is notionally the unit buy times unit price.

- Ordering cost is the administrative overhead cost to place an order; although in practice DLA ties this to the dollar size of an order, SAMMS treats a supply center's ordering cost as constant.

- Safety level is stock that exists to permit operations when normal inventory activity is disturbed.

- TVC is the sum of holding, material, and ordering costs.

2. These are the assumptions behind the PLT savings formula:

- Demand is constant.

- If PLT and EOQ remain unchanged, onhand inventory level is perfectly predictable and periodic. The inventory level:

  -- Resembles a sawtooth diagram when graphed.
  -- Rises by the EOQ when onhand inventory hits the safety level.
  -- Material and ordering costs are assessed when the purchase arrives.

- If PLT or EOQ change, then the first new order arrives when the new PLT ends or the new lower safety level is encountered, whichever is later. Any backorders do not incur penalty costs.

- If PLT falls and the safety level rises, then the first new order arrives when it would have had no changes occurred.

3. PLT savings is the total cost difference due to changes in PLT/price. These costs rely on the old and new EOQ/safety level as determined by the Wilson EOQ formula (Appendix C) and the Presutti-Trepp safety level formula (Appendix D).

4. Stated another way, PLT savings is the difference in TVC due to changed PLT and price. Given constant values for PLT, unit price, and a time period (years) $T = [0, t_2]$ that starts *at the beginning of a procurement cycle*, let:

- eoq(Price) be the unit size of an order (reference (a) and Appendix B)
- n(T,Price) be the integer number of times an order is placed during T
- slevel(PLT,Price) be the safety level (reference (b),(d); Appendix D)
- tvc(T,PLT,Price) be total variable cost of an item's stock during T

More explicitly:

tvc(T,PLT,Price)
=
MaterialCost(T,Price) + OrderCost(T) + HoldCost(T,PLT,Price)

where

- MaterialCost(T,Price) = eoq(Price) * Price * n(T,Price)

- OrderCost(T) = ordering cost * n(T,Price)

- HoldCost(T,PLT,Price)
  = holding cost of safety level + holding cost of EOQ
  = HoldCostSLevel(T,PLT,Price) + HoldCostEOQ(T,Price)

5. DLA computes the annual holding cost of one item by multiplying its price by a (supply center unique) holding rate (reference (c)). Unless something happens to change inventory activity from its periodic "sawtooth" activity, safety level is never consumed and so always contributes holding cost:

HoldCostSLevel(T,PLT,Price)
=
length(T) * Price * slevel(PLT,Price) * holdrate

Since demand depletes EOQ, the holding cost of EOQ relies upon the average accrued EOQ during T. In general, T holds several entire procurement cycles plus part of a cycle cut short. Since cycle length (years) is EOQ divided by annual demand:

HoldCostEOQ(T,Price)
=
holding cost of whole parts + holding cost of partial cycle
=
$n(T,Price) * \frac{1}{2}eoq^2(Price) * AnnualDemand^{-1} * Price * holdrate$
+
$Price * holdrate * (eoq(Price) - \frac{1}{2}AnnualDemand*FLength) * FLength$

where FLength is the length of the partial cycle, i.e.:

FLength = length(T) - n(T,Price) * eoq(Price) / AnnualDemand

This concludes discussion of TVC.

6. PLT savings is notionally the difference in costs of two inventory activities which--as assumed--resemble sawtooth diagrams. The first activity is based on current EOQ and safety level, while the second activity is based on new EOQ and safety level. In general, new activity may consume existing safety stock before jumping when the new buy arrives, at which time activity begins a new periodic flow. The PLT savings period begins when the old and new activity diagrams start to differ. This coincidentally occurs at the beginning of an old buy cycle.

7. The PLT savings period $T = [0, t_2]$ has subperiods T1 and T2:

- $T1 = [0,t_1)$ is the waiting time for the first new buy; T1 goes up to but does not include t_1
- $T2 = [t_1, t_2]$ starts where T1 ends and continues to the end of T
- t_1 and t_2 are in years

If $PLT_0/Price_0$ and $PLT_1/Price_1$ are the old and new PLT/price respectively, then PLT savings is:

$$\begin{gathered} \mathrm{PLTsavings(T)} \\ = \\ \mathrm{tvc}(T,PLT_0,Price_0) - [\mathrm{OneTimeHoldCost} + \mathrm{RecoverCost} + \mathrm{tvc}(T2,PLT_1,Price_1)] \end{gathered}$$

where:

- OneTimeHoldCost is the holding cost during T1
- RecoverCost is the material cost to cover the backorders and recover to the new safety level; thus the first new buy includes more than the new EOQ

8. OneTimeHoldCost depends on t_1 (see assumptions):

- if PLT rises, t_1 initially equals the difference in PLT (years)
  - -- if onhand stock at t_1 exceeds the new safety level, t_1 increases to when onhand stock is reduced to the new safety level
- if PLT and safety level both drop, t_1 is when onhand stock reaches the new safety level
- if PLT falls and safety level rises, $t_1 = 0$

If $SLevel_0$ and $SLevel_1$ are the old and new safety levels respectively, then t_1 equals:

$$\begin{gathered} \{\{\mathrm{deltaPLT} > 0\}\} * \max(\mathrm{deltaPLT}_{years}, X) \\ + \\ \{\{\mathrm{deltaPLT} \le 0\}\} * \{\{SLevel_1 \le SLevel_0\}\} * X \end{gathered}$$

where:

- $deltaPLT = PLT_1 - PLT_0$
- $X = (SLevel_0 - SLevel_1) / AnnualDemand$
- {{Statement}} is a boolean variable: 1 if Statement is true, else 0

9. OneTimeHoldCost also depends on the average onhand stock during T1. This equals:

$$AvgStock = \tfrac{1}{2}(SLevel_0 + \max(H,0))$$

where $H = SLevel_0 - AnnualDemand*t_1$. Thus:

$$OneTimeHoldCost = Price_0 * holdrate * AvgStock * t_1$$

10. The last variable left to compute for PLT savings is RecoverCost:

$$\begin{aligned} &RecoverCost \\ &= \\ &BackorderRecoveryCost + RecoverToNewSafetyLevelCost \\ &= \\ &Price_1 * \left| \min(0,H) \right| \\ &+ \\ &Price_1 * \{\{H < SLevel_1\}\} * (SLevel_1 - \max(H,0)) \end{aligned}$$

where as before, {{Statement}} is a boolean variable.

11. The above development is summarized below. Let:

- PLT_0 and PLT_1 be the old and new Production Leadtimes

- $Price_0$ and $Price_1$ be the old and new unit prices

- $EOQ_i = eoq(Price_i)$ (reference (a) and Appendix C)

- $SLevel_i = slevel(PLT_i, Price_i)$ (reference (b) and Appendix D)

- n(Period,Price) = integer # of times an order is placed during Period
  = int [length(Period) / length(procurement cycle)]
  = int [length(Period) * AnnualDemand / eoq(Price)]

Let $T = [0,t_2] = [0, t_1) \cup [t_1, t_2]$ be the PLT savings period (years)

- time 0 is when old and new inventories first depart

- time 0 also starts an old buy cycle

- {{Statement}} is boolean: 1 if Statement is true, 0 if false

- first new buy arrives at time t_1 =

$$\{\{PLT_1 > PLT_0\}\} * \max((PLT_1-PLT_0)_{years}, (SLevel_0-SLevel_1) / AnnualDemand)$$

$$+$$

$$\{\{PLT_1 \le PLT_0\}\} * \{\{SLevel_1 \le SLevel_0\}\} * (SLevel_0-SLevel_1) / AnnualDemand$$

- $H = SLevel_0 - AnnualDemand*t_1$

The PLT savings formula during period T is:

$$
\begin{array}{cr}
PLTsavings(T) & \\
= & \\
tvc(T, PLT_0, Price_0) & \\
- & \\
Price_0 * holdrate * \tfrac{1}{2}(SLevel_0 + \max(H,0)) * t_1 & \text{(onetime holding cost)} \\
- & \\
Price_1 * \left| \min(0,H) \right| & \text{(backorder recovery)} \\
- & \\
Price_1 * \{\{H < SLevel_1\}\} * (SLevel_1 - \max(H,0)) & \text{(recover safetylevel)} \\
- & \\
tvc([t_1, t_2], PLT_1, Price_1)] &
\end{array}
$$

where for a general time horizon Period that begins with that of a buy cycle:

$$
\begin{array}{cr}
tvc(Period, PLT, Price) & \\
= & \\
eoq(Price) * Price * n(Period, Price) & \text{(Material Cost)} \\
+ & \\
ordering\ cost * n(Period, Price) & \text{(Cost to Order)} \\
+ & \\
length(Period) * Price * slevel(PLT, Price) * holdrate & \text{(HoldCost Safety)} \\
+ & \\
\left.\begin{array}{c} n(Period, Price) * \tfrac{1}{2}eoq^2(Price) * AnnualDemand^{-1} * Price * holdrate \\ + \\ Price * holdrate * (eoq(Price) - \tfrac{1}{2}AnnualDemand*FLength) * FLength \end{array}\right\} & \text{EOQ Hold Costs}
\end{array}
$$

and

$$FLength = length(Period) - n(Period, Price) * eoq(Price) / AnnualDemand$$

APPENDIX C
EOQ COMPUTATIONS

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EOQ COMPUTATIONS

1. References:

   a. DLAM 4140.2 Vol II Part 2 D186 "EOQ Computation"
   b. DLAM 4140.2 Vol II Part 2 D187 "Safety Level Computation"
   c. "Multiple Cost EOQ Study", Synergy Inc. (December 1989)

2. SAMMS computes EOQ for replenishment items only (Item Category Code equal 1 or P). There are two ways to express the EOQ: as the dollar value of the buy ($EOQ) and as the number of units bought (EOQ_{units}). SAMMS uses the Wilson formula to compute $EOQ (reference (a)):

$$
\begin{aligned}
\$EOQ &= [(2*SetUpCost*4*QFD*Price)/HoldingRate]^{1/2} \\
&= T*(QFD*Price)^{1/2}
\end{aligned}
$$

where QFD is Quarterly Forecasted Demand (or Quarterly Forecasted Demand New if Age of Item doesn't equal E), Price is the unit's price, and T is a uniform system constant (the "T-Factor") determined by each supply center:

$$T = (8*SetUpCost/HoldingRate)^{1/2} \qquad [1]$$

3. To compute EOQ_{units}, SAMMS doesn't simply divide $EOQ by Price. Rather, EOQ_{units} is based on procurement cycle length. SAMMS also forces EOQ_{units} to be between a quarter's and three years' demand. Here's how SAMMS determines cycle length (references (a),(c)):

- $QFD = dollar amount of QFD = Price * QFD

- if $\$QFD <= M_1 = T^2/144$ then CycleLengthMonths = 36 (i.e., buy a three year supply)

- elseif $\$QFD <= M_2 = T^2/4$ then:

  -- EOQ_{units} = $EOQ / Price

  -- CycleLengthYears = EOQ_{units} / (4*QFD)

  -- CycleLengthMonths = int(CycleLengthYears * 12) [2]
  = int(3 * EOQ_{units} / QFD)

  where int(x) is the whole part of x, e.g., int(3.9) = 3, int(4) = 4

- elseif $\$QFD <= M_3 = T^2$ then CycleLengthMonths = 6

- else CycleLengthMonths = 3

- if the item's Shelf Life falls between 1 and 29 months inclusive, then CycleLengthMonths = min(CycleLengthMonths,6).

4. Now that Procurement Cycle Length is known, reference (b) tells how to compute EOQ_{units} for use in Safety Level calculations:

$$\boxed{EOQ_{units} = (QFD / 3) * CycleLengthMonths} \qquad [3]$$

5. All the foregoing is IAW reference (a). However, at present (February 1992) the supply centers set M_2 equal to M_3, i.e., $M_2 = T^2$. The 36 month cap on cycle length is also changing. Here's how these changes affect EOQ computations. Let X be the cap on cycle length (X measured in quarters and not months; thus a 24 month cap implies X = 8):

- if $\$QFD \le M_1 = T^2 / X^2$ then CycleLengthMonths = 3X

- elseif $\$QFD \le M_3 = T^2$ then CycleLengthMonths is given in equation [2]

- else CycleLengthMonths = 3

- if the item's Shelf Life falls between 1 and 29 months inclusive, then CycleLengthMonths = min(CycleLengthMonths, 6).

EOQ_{units} is then computed using [3].

6. Finally, the following method offers a way to adjust EOQ computations when actual data violates SAMMS computations and when CycleLength is computed as in the previous paragraph. This method simply adjusts the T-Factor to make computations agree with reality. The resulting T-Factor is specific for that item.

7. If the holding rate is constant, then the only way to alter the T-Factor (equation [1]) is to change SetUpCost. Setting aside the limitations imposed by shelf life upon Cycle Length, this Length either equals or exceeds three months. If it equals three months, then:

$$\$QFD > T^2 = 8*SetUpCost / HoldingRate$$

and so

$$SetUpCost < HoldingRate * \$QFD / 8 \qquad [4]$$

8. If Cycle Length exceeds three months, then we assume that Cycle Length doesn't exceed the SAMMS cap. In this case, let L equal Cycle Length in months. From equation [2], L = int(3*EOQ/QFD) and per paragraph 2 we get:

$$L = int(3T / sqrt(\$QFD))$$

Now choose T so that L = 3T / sqrt($QFD). Thus:

$$L * sqrt(\$QFD) = 3T$$
$$L^2 * \$QFD = 9T^2 = 72*SetUpCost / HoldingRate$$

which gives:

$$SetUpCost = HoldingRate * CycleLengthMonths^2 * \$QFD / 72 \quad [5]$$

It's easy to see that if L equals three months, then [5] yields [4]. Thus [5] can be used to recompute SetUpCost regardless of CycleLength.

9. Now to consider the effects of shelf life upon these computations. If the shelf life lies between 1 and 29 months inclusive, then:

$$CycleLengthMonths = \min(6,L)$$

where L is computed as before. If CycleLengthMonths doesn't equal 6, then [5] still remains in force. Otherwise, L must equal or exceed six months and since L = 3T / sqrt($QFD):

$$3T / \mathrm{sqrt}(\$QFD) \geq 6$$

which implies:

$$4 * \$QFD \leq T^2 = 8*SetUpCost / HoldingRate$$

and so:

$$SetUpCost \geq \tfrac{1}{2}HoldingRate * \$QFD$$

But the right hand side of this inequality is simply [5] evaluated at CycleLengthMonths = 6. Thus for all items:

$$\boxed{SetUpCost = HoldingRate * CycleLengthMonths^2 * \$QFD / 72}$$

To reconcile SAMMS EOQ computations with observed actual values, simply use the above value of SetUpCost in equation [1].

APPENDIX D
VARIABLE SAFETY LEVEL (VSL) FOR DEMAND ORIENTED REPLENISHMENT ITEMS

APPENDIX D

VARIABLE SAFETY LEVEL (VSL) FOR DEMAND ORIENTED REPLENISHMENT ITEMS

References:

a. DLAM 4140.2 Vol II Part 2 D187 "Safety Level Computation"
b. "More Ado About EOQ", Naval Research Logistics Quarterly, June 1970

1. The Presutti-Trepp VSL formula relies on these variables found in the supply center's Supply Control File and Management Policy Tables:

ALPHA	ALPHA factor (Table 008)	QFD	Quarterly Forecasted Demand
ALT	Administrative Leadtime	S	Average Requisition Size
BRate	Backorder Rate (Table 007)	S_C	System Constant (Table 007)
C	Unit Price	VSL	Variable Safety Level
MAD	Mean Absolute Deviation of Demand	Z	Safety Level Essentiality

2. Boolean logic statements will serve here as shorthand for if..then statements. Such a statement looks like {{today is Monday}}. If this is true, then the statement equals one. If false it equals zero.

3. The economic order quantity (Appendix C) is the number of units bought:

$$Q = EOQ_{units} = (QFD / 3) * CycleLengthMonths$$

the total procurement leadtime is:

$$PALT = (ProductionLeadtime + AdministrativeLeadtime)_{days}$$

and leadtime demand is:

$$LTD = round(QFD*PALT/91)$$

4. Other variables are:

- MADLT = mean absolute deviation of leadtime demand = MAD(a+bT) where:

  -- a,b depend on ALPHA (reference (a), page 5)
  -- $T = \begin{cases} PALT_{quarters} & \text{nonVIP items} \\ PALT_{months} & \text{VIP and monthly items} \end{cases}$

- $R1 = 2.56*S*Q*C*BRate / (Z*S_C*MADLT*[1 - \{\{Q <= 3.54MADLT\}\}exp(-1.1313Q/MADLT)])$

- $X = \{\{\text{last 12 months had demand}\}\}*[3.75MADLT*\{\{R1 < .0144\}\} - \{\{R1 >= .0144\}\}*MADLT*.88387*ln(min(1,R1))]$

NOTE: the min(1,R1) term doesn't appear in reference (a) but is assumed.

5. Finally, the VSL is the rounded value of the minimum of X and LTD, i.e., VSL = round (min (X,LTD)). However, weapon system items (Weapon System Indicator Code = F,L,T as of March 1992 and not W-Z as in reference (a))

undergo another computation to augment safety level. The higher of the VSL and augmented safety level becomes the final safety level. This study, however, ignores augmented safety level.

ADJUSTING VSL TO AGREE WITH SAMMS

1. We seek the "correct" System Ratio (Backorder Goal / System Constant) that when used in the SAMMS VSL formula gives a computed VSL that equals what is actually in SAMMS. The following holds for any replenishment item (Item Category Code = 1,P) having a variable safety level. Pertinent equations from the preceeding SAMMS VSL formula are:

$$R1 = 2.56*S*Q*C*BRate / (Z*S_c*MADLT*[1 - \{\{Q <= 3.54MADLT\}\}exp(-1.1313Q/MADLT)])$$

$$X = \{\{\text{last 12 months had demand}\}\}*[3.75MADLT*\{\{R1 < .0144\}\} - \{\{R1 >= .0144\}\}*MADLT*.88387*ln(min(1,R1))]$$

Actual SLevel = round(min(X,LTD)) (ignores augmented safety level)

2. In order to streamline later computations, re-express these equations:

$$\text{Actual SLevel} = VSL = min(X,LTD) \quad [1]$$

$$\text{where } X = \delta_1*[\delta_2*3.75MADLT - \delta_3 0.88387*MADLT*ln(min(1,R_1))]$$
$$= \delta_1*[\delta_2*\alpha_2 - \delta_3\alpha_3 ln(min(1,R1))] \quad [2]$$

and:

- $\delta_1 = \{\{\text{last 12 months had demand}\}\}$
- $\delta_2 = \{\{R_1 < .0144\}\}$ [2.1]
- $\delta_3 = \{\{R_1 \geq .0144\}\}$ [2.2]
- $\alpha_2 = 3.75*MADLT$
- $\alpha_3 = 0.88387*MADLT$

$$\text{Let } R_1 = L*2.56*S*Q*C / [Z*MADLT(1-\delta_4 exp(-1.1313Q/MADLT)]$$
$$= \alpha_4 L / (1-\delta_4\alpha_5), \text{ where:} \quad [2.3]$$

- L = System Ratio = BackOrderGoal / SystemConstant
- $\delta_4 = \{\{Q / MADLT \leq 3.54\}\}$ [3]
- $\alpha_4 = 2.56*S*Q*C / (Z*MADLT)$ [4]
- $\alpha_5 = exp(-1.1313Q/MADLT)$ [5]

3. To determine System Ratio, [1] says that VSL must equal X. Otherwise, if VSL = LTD--and since LTD is independent of the System Ratio--then the System Ratio cannot be computed directly (although it can be bounded). Thus, in order to recover the "correct" System Ratio, the first criterion that the item must meet is:

$$0 < \text{Actual SLevel} < LTD$$
$$(\text{i.e., } X = VSL) \quad [5.1]$$

Equation [2] says that δ_1 must equal one (or else everything is zeroed out). Thus the second criterion that the item must meet is:

$$\text{Demand in the last twelve months} > 0$$
$$(\text{i.e., } \delta_1 = 1) \quad [5.2]$$

Equations [3]-[5] require MADLT > 0. Since the MAD Multiplier is always strictly greater than 0 (DLAM 4140.2 VOL II Part 2, D187-5), the third criterion is:

$$\text{MAD} > 0 \qquad [5.3]$$

4. Equation [2.3] requires that α_4 not equal zero (otherwise L can't be recovered). Thus the fourth criterion is:

$$\text{Average Requisition Size} > 0 \qquad [5.4]$$

Finally, from equation [2], if $\delta_3 = 0$, then $\delta_2 = 1$ and at best we could only bound the System Ratio. Thus the fifth criterion is:

$$\delta_3 = 1 \qquad [6]$$
$$(\text{i.e., } R_1 \geq .0144 \text{ and } \delta_2 = 0)$$
$$(\text{will be shown equivalent to VSL} \leq 3.75*\text{MADLT})$$

5. Even though R_1 isn't captured in system, there is a way to determine if $\delta_3 = 1$. From [2.1] and [2.2], $\delta_3 = 0$ if and only if $\delta_2 = 1$. If $\delta_2 = 1$, then [2] becomes:

$$X = \alpha_2$$
$$= 3.75*\text{MADLT (by definition)} \qquad [6.1]$$

But since the items we're looking at obey [5.1], X = VSL = 3.75*MADLT. Thus by contrapositive, if VSL doesn't equal 3.75*MADLT, then δ_2 can't equal one and so $\delta_3 = 1$.

6. Now assume that the item meets all five criteria (paragraph 3). Using [5.1], [5.2], and [6], [2] yields:

$$\alpha_3 \ln(\min(1,R_1)) = -\text{VSL} < 0 \qquad [7]$$

Since $\alpha_3 > 0$, [7] yields:

$$\ln(\min(1,R_1)) < 0$$

If $\min(1,R_1) = 1$, then $\ln(1) = 0 < 0$, a contradiction. Thus $\min(1,R_1) = R_1$ and [7] becomes:

$$\alpha_3 \ln(R_1) = -\text{VSL} \implies R_1 = \exp(-\text{VSL}/\alpha_3) \qquad [8]$$

7. Equating [2.3] and [8] yields:

$$\boxed{L = [(1-\delta_4\alpha_5) \,/\, \alpha_4] \exp(-\text{VSL}/\alpha_3)} \qquad [9]$$

However we must check that this value for L is consistent with $\delta_3 = 1$ as given above. Substituting [9] into [2.3] and simplifying yields VSL must not exceed 3.75*MADLT. If this is true, then [9] recovers the System Ratio.

8. By making some assumptions, there's a way to handle affected items that

fail the criteria. These assumptions may be valid since the items at issue are already abnormal because they violate SAMMS computations. If the item has had no annual demand (i.e., $\delta_1 = 0$) then any computed SLevel will equal zero and there's no need to recover a System Ratio. Thus only consider items where $\delta_1 = 1$. Furthermore, MAD must be nonzero in order for SAMMS computations to be tractable. Thus α_2 and α_3 are nonzero. Finally, it will become clear below that α_4 must be nonzero. From [4], SAMMS forces Z to be nonzero and it's safe to assume that EOQ and Unit Price are nonzero. Thus only S--the average requisition size--could make α_4 nonzero. Thus we assume S is nonzero otherwise System Ratio cannot be recovered.

9. Paragraph 1 gives VSL = min(X,LTD). To recover the System Ratio, VSL must equal X. Thus assume:

$$VSL = \delta_2 * \alpha_2 - \delta_3\alpha_3 \ln(\min(1,R_1)) \qquad [10]$$

If VSL > LTD then SAMMS computations have been violated, and so this is as good an assumption as any. If VSL < LTD then [10] must hold according to SAMMS.

10. Case #1: VSL = 0. From [10] we get:

$$\delta_2\alpha_2 = \delta_3\alpha_3 \ln(\min(1,R_1)) \qquad [11]$$

If we assume that $\delta_2 = 1$, then δ_3 must equal zero and from [11], $\delta_2\alpha_2 = 0$, a contradiction. Thus δ_2 must equal zero and so δ_3 equals one. Thus, $\ln(\min(1,R1)) = 0$ and so $R_1 \geq 1$. This together with [2.3] implies that

$$L \geq (1-\delta_4\alpha_5) / \alpha_4$$

If SRatio is the System Ratio currently in effect, then let the recovered System Ratio be:

$$L = \max(SRatio, (1-\delta_4\alpha_5)/\alpha_4)$$

11. Case #2: VSL > 0. If $\delta_2 = 0$ then $\delta_3 = 1$. From [10] we thus get

$$VSL = -\alpha_3 \ln(\min(1,R_1))$$

and since this is simply [7] repeated, we conclude that [9] is the recovered System Ratio--provided (as before) VSL doesn't exceed 3.75*MADLT. If VSL > 3.75*MADLT, then $\delta_2 = 1$ and so $R_1 < .0144$. This implies that $L < .0144(1-\delta_4\alpha_5) / \alpha_4$ and if SRatio is the System Ratio currently in effect, then let the recovered System Ratio be:

$$L = \min(SRatio, .0144(1-\delta_4\alpha_5) / \alpha_4)$$

12. Outcasts. According to the SAMMS safety level formula, items that had no demand in the last twelve months receive a safety level of zero. If such an item has a nonzero safety level, then treat it as a fixed safety level item. However, if an item's actual safety level exceeds its leadtime demand (a violation of the SAMMS safety level formula), then for the purposes of computing PLT savings, then it may be necessary to bring the safety level down to the leadtime demand cap.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 1992	Final

4. TITLE AND SUBTITLE
Computation of Production Leadtime Savings

5. FUNDING NUMBERS

6. AUTHOR(S)
Maj Bruce Colletti, USAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
HQ Defense Logistics Agency
Operations Research & Economic Analysis Office (DLA-LO)
Cameron Station
Alexandria, VA 22304-6100

8. PERFORMING ORGANIZATION REPORT NUMBER
DLA-93-P10096

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQ Defense Logistics Agency
Engineering Programs Division (DLA-SE)
Cameron Station
Alexandria, VA 22304-6100

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)

A new methodology allows Defense Logistics Agency value engineers to compute system-wide dollar savings associated with changing an item's PLT and/or price. The methodology considers total variable costs, item specific data, supply center specific rates, and other variables. Standard Automated Material Management System formulas for economic order quantity (EOQ) and safety level formulas are used. New formulas reconcile differences between actual and computed EOQ and safety level. The methodology replaces another whose accuracy has often been questioned since the early 1980's. The new methodology has been implemented on a personal computer as an analysis tool. This tool permits rapid item-specific study, produces two savings reports (one includes material costs while the other doesn't), displays graphs, and has embedded help texts. A companion data building tool stores item data that will be used by the savings tool.

14. SUBJECT TERMS
production lead time, savings, safety level, economic order quantity

15. NUMBER OF PAGES
48

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	